Ancillary Savings and Production Benefits in the Evaluation of Industrial Energy Efficiency Measures

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ABSTRACT

This paper examines the importance of ancillary savings and production benefits that occur when energy efficiency measures are implemented in industrial facilities. We review results from 81 energy efficiency projects that were developed into separate case studies for the U.S. DOE's Office of Energy Efficiency and Renewable Energy (EERE). We then use a methodology to assess and quantify the energy and ancillary benefits, including production benefits, of these projects and then integrate them in the economic evaluation of these energy efficiency projects. This methodology yields a more comprehensive Cost of Conserved Energy (CCE), which can be directly compared to the cost of energy.

The case study assessment shows that ancillary savings and production benefits are quantifiable in 54 of the case studies in the sample (67.8%). The paper compares the CCE values for the data set with ancillary savings and production benefits against CCE values for the data set without such benefits and includes Conservation Supply Curves (CSC) for both sets of CCE values. CSCs are curves that display the cost of energy conservation. The analysis shows that for projects where ancillary savings and production benefits are part of the calculation, the CCE is less than the cost of energy, which signifies that in such cases it is more cost-effective to implement energy efficiency projects than to buy more energy. Since conventional modeling of payback calculations frequently omits ancillary savings and production benefits, the cost-effectiveness of such projects is grossly underestimated. The paper concludes with a detailed discussion of one of the projects in the sample.

Introduction

Assessments of industrial energy efficiency initiatives typically display the energy and energy cost savings from these efforts. Such energy cost savings are routinely factored into conventional models of payback calculations to demonstrate the desirability of energy efficiency. In several studies that have examined the effects of energy efficiency improvements in industrial and commercial facilities (Worrell, Laitner, Ruth & Finman, 2003 p. 1084; Boyd, 2000 p. 290; McKane, 1999 p. 326) a clear link has been found between such improvements and the occurrence of ancillary cost savings and productivity benefits. In this paper, ancillary savings refers to all quantifiable cost savings that result from an energy efficiency improvement that are not part of the energy savings from that improvement. These ancillary savings can sometimes be quite significant when compared to both the energy savings yielded by an energy efficiency project and that project's implementation costs (Worrell, Laitner, Ruth & Finman 2003 p. 1086; Rufo 2003, p. 14). When these ancillary savings are omitted from the project payback calculation models, the true impact of industrial energy efficiency measures is understated.

Common payback models used to evaluate the desirability of energy efficiency efforts include simple payback, net present value (NPV), and internal rate of return (IRR). Quantified energy and ancillary cost savings can be integrated into the calculations for these models; however, ancillary cost savings are often omitted from them. One potential reason is that ancillary savings are not achieved consistently. While such savings often accrue in the wake of an energy efficiency improvement, the same benefits are not obtained each time a project is implemented. Another reason is that time and skill are required to accurately track such benefits. Industrial plants need to develop baselines of their ancillary costs and doing so may be outside of a project's scope of work. Also, if the ancillary savings turn out to be minor, then tracking them may not be worth the expense. In addition, quantifying certain ancillary benefits can be difficult. Benefits such as longer equipment life, increased production reliability, better worker safety/morale, reduced noise levels, and improved air quality can be subjective or intangible.

In this study, we apply a model that includes ancillary cost savings and productivity gains that result from the energy efficiency projects in the evaluation of energy efficiency efforts. Because such benefits are at times significant, they can have a substantial impact on the predicted payback of a proposed improvement and effectively determine whether the improvement occurs. On an industry-wide level, the systematic inclusion of ancillary savings can change that industry's cost-effective potential for energy efficiency [Worrell, Laitner, Ruth & Finman, 2003 p. 1082]. Therefore, it is important to correctly and explicitly model these benefits into payback calculations in order to properly evaluate any given energy efficiency project.

We use the 'bottom up' Conservation Supply Curve (CSC) methodology illustrated in Worrell, Laitner, Ruth & Finman (2003, p. 1089) to analyze the energy and ancillary cost savings in our data set. The CSCs graphically display the cost of each unit of energy conserved as a result of an energy efficiency project against the per-unit cost of energy, allowing for an immediate comparison of the cost of saving energy with the cost of purchasing it. CSCs also serve to determine the cost-effectiveness provide of energy efficiency expenditures (Worrell, Laitner, Ruth & Finman, p. 1089; Rufo 2003, p. 2 and Stoft 1996, p. 3). The CSCs in this study are considered 'bottom up' because we use plant-level data for each energy efficiency project.

The key to producing CSCs is calculating the Cost of Conserved Energy (CCE). The CCE is a value of the annual, incremental cost per unit of energy conserved, and is therefore the marginal cost of conserved energy. Generally, the CCE is calculated by dividing the total cost of an energy efficiency measure by the present value of that measure's lifetime energy savings (Stoft 1995, p. 3). This allows the CCE to be expressed in dollars per unit of energy and therefore, to be compared against the cost of energy. Typically in a CSC, the CCE values are plotted vertically in order of lowest to highest (Stoft 1995, p. 3).

We begin with a summary of the data and then discuss the types of ancillary benefits in the study and how they are quantified. Next, we present the methodology and discuss the results. An example of a successful energy efficiency project is provided to demonstrate the difference between an analysis that includes ancillary savings versus one that omits them. Finally, some concluding remarks are presented.

Data

The data in this study is obtained from a set of 81 case studies that were developed by the U.S. DOE's Office of Energy Efficiency and Renewable Energy (EERE) between 1998 and 2004. Each case study describes an energy efficiency project that occurred in an industrial facility in the U.S and the results that the project yielded. Of these 81 case studies, 40 were developed and published under the EERE's BestPractices program. Twenty-two of the case studies were based on Plant-Wide Assessments (PWAs) and eighteen case studies were produced in support of DOE-sponsored conferences on energy efficiency.

All 81 projects were implemented in accordance with a plant or system-specific strategy designed to increase the energy efficiency of the processes or industrial systems at the sites where those systems were located. Each project in the data set has well documented energy and energy cost savings. Of the 81 total projects, 54 (66.7%) include quantified ancillary cost savings and production benefits that are related to the energy efficiency measures that were implemented. Data on ancillary cost savings and production benefits was collected from the individual firms and corroborated by consultants or vendors involved with the projects. For all 81 projects, the following data points were recorded: Energy savings in kilowatt-hours for electricity, MMBtu for natural gas; energy cost savings, ancillary savings (when applicable); production benefits (when applicable) and total project costs. In addition, each project's simple payback using total project savings was recorded. The simple payback with only energy cost savings was then computed for all projects.

The measures designed to improve energy efficiency represented a variety of efficiency improvements including equipment replacement, technological upgrades and reconfiguration of existing equipment. In many cases, the projects were implemented in accordance with industry best practices for energy efficiency. The plants in which the projects occurred represent a wide range of manufacturing activities, with 52 of them (64%) falling under at least one of the DOE's energy intensive, Industries of the Future (IOF) categories. Seventeen others are classified as general manufacturing with food processing, textiles and utilities accounting for the remainder. In addition, the data set in the study provides a fairly balanced distribution of project sizes based on total annual savings – 16% have annual project savings of $49,000 or less, 44% have annual project savings between $50,000 and $249,000, 20% have annual project savings between $250,000 and $499,000, 9% have annual project savings between $500,000 and $749,000, and 9% have annual project savings that exceed $750,000. However, the projects in the study are not a random sample and the sample size is small relative to the total number of energy efficiency efforts/projects that occur annually in the U.S. The projects are also geographically concentrated, with approximately two-thirds occurring on the West Coast and several Midwest states. In addition, the sample does not contain projects that were deemed unsuccessful (i.e., anticipated energy savings were not achieved or payback periods considered unattractive).

Types of Ancillary Savings and Production Benefits

The majority of the ancillary savings and production benefits yielded by the projects in the sample fall into five principal categories: Operations and Maintenance (O&M), Production, Work Environment, Environmental and Other. The specific benefits in each of these categories are listed in Table 1.

Table 1: Types of Ancillary Savings and Production Benefits from Energy Efficiency Measures

Operations and Maintenance	Production
Reduced maintenance costs	Reduced product waste
Reduced purchases of ancillary materials	Increased Production
Reduced water consumption	Improved product quality
Lower cooling requirements	Increased production reliability
Reduced labor costs	Shorter process/cycle time
Lower costs of treatment chemicals	
Work Environment	**Environmental**
Increased worker safety	Reduced hazardous waste
Reduced noise levels	Reduced dust emissions
Improved workstation air quality	Reduced waste water output
	Reduced CO, CO_2, NO_x, SO_x emissions
Other	
Achieved rebate/incentive (one-time)	
Reduced/eliminated demand charges	
Reduced/eliminated rental equipment costs	
Avoided/delayed costs (one-time)	

In the O&M category (38 projects), most of the quantified ancillary savings were recorded in situations in which less equipment and machinery was in use after a project was complete (i.e., if a plant routinely operated four pumps before a project, but only needed to operate three pumps once the project was complete). This required less time of technicians, and fewer changes of lubricants, filters and other materials. Sometimes, O&M cost savings occurred when aging equipment that required frequent repairs before a project was replaced with new equipment that did not fail. Savings in this category were also registered when certain equipment was converted from being water-cooled to being air-cooled and when certain processes were modified to recycle or use less water.

Many of the quantified benefits in the production category (9 projects) were revenue increases. In some cases these revenue increases were due to higher output because the production equipment was made more efficient (shorter process time). At other times, production increased and became more reliable because there were fewer or almost no equipment shutdowns after the projects' completion. In other cases, product quality improvements led to significant reductions in product waste and warranty claims, which yielded cost savings.

Several projects reported improved working conditions and environmental benefits. The improved working conditions, which included better worker safety, lower noise and better air quality from lower amounts of dust; along with lower emissions of CO_2, SO_x and NO_x, were not quantifiable and were not included in the model. However, other environmental benefits such as reductions in wastewater or wastewater treatment chemicals were quantified for several projects in the data set and were included in the model.

Finally, other financial benefits were quantified for thirteen projects. These benefits included utility or state-sponsored rebates and incentives as well as demand charge reductions, avoided capital and other costs. In a few cases, rental equipment that was necessary to support production before a project was no longer needed after the project's completion, which yielded rental equipment cost savings.

Methodology for Including Ancillary Savings and Production Benefits (Cost of Conserving Energy)

We apply the approach described in Worrell, Laitner, Hodaya & Finman (2003, p. 1088) in evaluating ancillary and production benefits of the projects in the data set. This approach provides a formal and transparent process for analyzing ancillary savings. While many of the projects in this study already possessed quantified ancillary cost savings and production benefits, this approach was useful to convert those benefits that were not immediately quantified into cost impacts.

Once all of the ancillary savings from the projects in the sample were quantified, the CCE values were computed for each project in the sample and were used to produce two sets of CSCs. The first set compares the CSC composed of CCE values with ancillary savings and production benefits against the individual energy costs of the plants in the data set. If the CCE values were greater than the plants' energy costs, the energy efficiency measures were viewed as not cost-effective. If the CCE values were below those costs, the energy efficiency measures were viewed as cost-effective and worthwhile. The next set of CSCs compares the one that contains CCE values without ancillary savings and production benefits against a CSC with CCE values that includes those benefits.

Generally, the costs of energy efficiency projects are incurred in less than one year (during the project's implementation), while the savings follow over a number of years after the project's completion. This creates a problem in that the cost and benefit streams differ. To make these streams correspond, a capital cost recovery factor is built into the CCE, which annualizes the project costs. The capital cost recovery factor includes a discount rate that reflects the cost of capital with a risk premium, and the lifetime of the project. In this study, we assume a project life of 10 years based on prior research [Lung, McKane, and Olszewski]. It should be noted that a 10-year project life might not be universal due to the different methodologies towards energy efficiency. The discount rate used is 7% and it is based on the yield on the 10-year US Treasury bond between 1998 and 2004 as well as a risk premium of between 2% and 3%. As a result, the CCE represents the total of the annualized project costs and the incremental ancillary costs (benefits), divided by the annual energy savings. The CCE model from Worrell, Laitner, Ruth & Finman (2003, p. 1089) takes the form:

$$\text{CCE} = \frac{(I*q) + M}{S} \quad \text{(expressed in \$/GJ)}$$

Where

$$q = \frac{d}{[1-(1+d)^{-n}]}$$

and

CCE = cost of conserved energy per energy efficiency project ($/GJ)
I = capital costs ($)
M = annual change in O&M costs
S = annual energy savings (GJ)
q = capital recovery factor
d = discount rate
n = life span of project savings (years)

To factor in all of the quantified ancillary savings and production benefits in the data set, the CCE with ancillary savings and production benefits in this study takes the form:

$$\text{CCE} = \frac{[TC - (AC+R)*q] + M - B}{S}$$

where

TC = total project and capital costs ($)
M = annual change in O&M costs
S = annual energy savings (GJ)
AC = total avoided capital costs (capital purchases that were obviated by the success of the energy efficiency measure)
R = total rebate/incentive payments
B = total annual production benefits

and

$$q = \frac{d}{[1-(1+d)^{-n}]} = \frac{(0.07)}{[1-(1+.07)^{-10}]} = .1424$$

Because the energy savings in the data set included electricity (kWh) and natural gas (MMBtu), all energy units and savings in the data set were converted into Gigajoules (GJ) prior to calculating the CCE values to render the energy units uniform. This allows the CCE values (presented in $/GJ) to be directly compared with the individual energy costs of the plants in the sample. Once the CCE values were calculated, they were ranked in order from lowest to highest and plotted successively along the y-axis to construct the CSCs.

Results

The findings provided by the analysis of the data were insightful and somewhat surprising. As anticipated, ancillary savings and production benefits had a visible impact on the CCE values. The aggregate annual cost savings for all 81 projects, including the ancillary savings, came to $68.7 million. The annual ancillary savings totaled $21 million, representing almost 31% of total project savings and the total annual energy cost savings were $47.7 million or 69% of the total savings. With total project costs for all 81 projects summing to $68.2 million, the simple payback including ancillary savings is slightly less than one year. When based on the energy cost savings alone, the simple payback jumps to 1.43 years. These results are summarized in Table 2.

Table 2: Summary Data

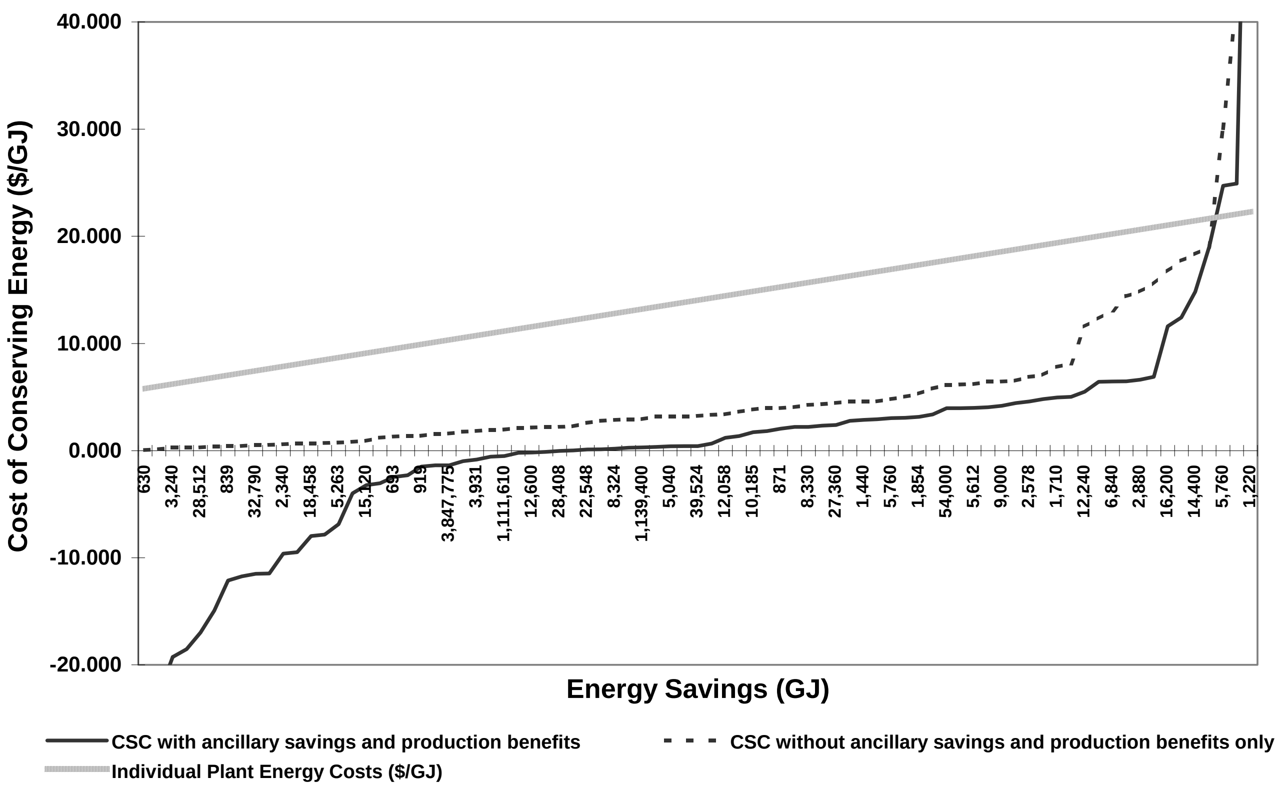
Total project costs	$68,219,115
Total annual energy savings	$47,662,220
Total annual non-energy savings	$21,080,449
Total annual savings	$68,742,669
Simple payback of energy savings	1.43
Simple payback with non-energy benefits	0.99

With respect to the CCE analysis, the ancillary savings and production benefits had more of an impact on the shape of the CSC than on the relationship between the CCE calculations and the energy costs of the plants in the data set. When ancillary savings and production benefits were included in the CCE calculations, the CCE values became smaller, indicating a lower cost of conserving energy. This caused the CSC to shift downward and to the right. Also, the inclusion of ancillary benefits caused the CCE values to be smaller than the energy costs of 79 of the plants in the data set (97.5%). This signifies that for each of those 79 plants, it was more cost effective to implement the energy efficiency improvement than to continue purchasing the amounts of energy required before the improvement. Both of the plants whose CCE values were above their respective energy costs incurred substantial capital costs for their energy efficiency projects, which resulted in higher relative project costs. In addition, one of those projects was implemented with the primary goal of ensuring production reliability, which we were not able to quantify. Had this extra reliability been quantified, it could have lowered the CCE for that plant.

When the ancillary savings and production benefits were excluded from the data set, the number of plants whose CCE values were lower than each plant's associated energy cost fell to 75 (92.5%). The six plants for which the CCE is higher than the cost of energy include the two that had the relatively high capital costs and four others for which the ancillary savings were quite substantial. This can be seen in Figure 1 where the CSCs are compared with the normalized energy costs for the plants in the data set.

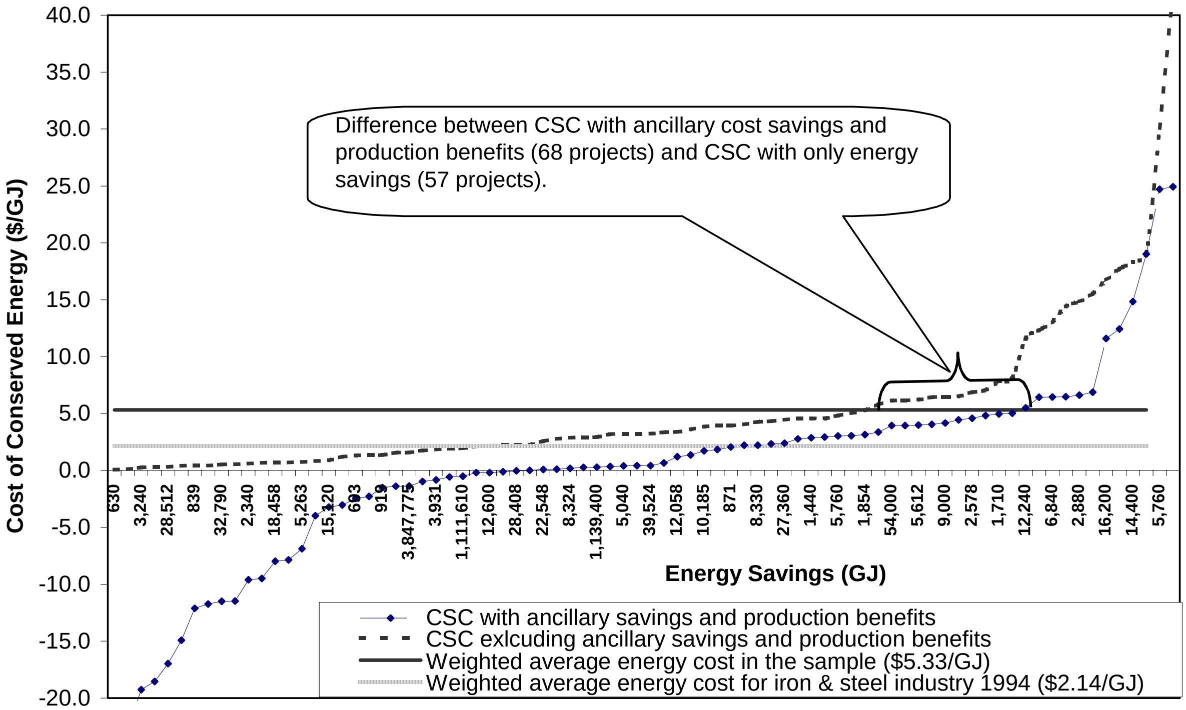
The high percentage of CCE values based only on energy savings that were below the plants' respective energy costs was surprising. Three reasons help explain why the energy costs in the data set are so high. Many of the projects in the sample were implemented between 2000 and 2003 when energy costs were historically high. The simple average of the reported energy costs for all 81 projects was $14.03/GJ. When this average was weighted by the energy cost savings for all 81 projects, this figure fell to just $5.33/GJ. Had the weighted average energy cost for the plants in this study been $2.14/GJ, as in the study by Worrell, Laitner, Hodaya & Finman (2003, p. 1090) for the iron and steel industry, 47 CCE values with ancillary savings and production benefits (58%) and 27 (33%) of the CCE values that excluded these benefits would be below this figure. Also, 29 of the projects in the data set occurred in California, which experienced dramatically higher energy costs than other parts of the U.S. during the period when the projects were implemented. Lastly, many of the projects in the data set were implemented with recommendations by industry experts and were devised to maximize energy savings. Therefore, for some projects the energy savings alone were quite important; in some cases, they reduced the pre-project energy consumption for the system being optimized by as much as 40%. As a result, the gap between the CSCs without ancillary savings and the CSCs that include them is not very wide.

Figure 1: Conservation Supply Curves and Individual Plant Energy Costs



When viewed against the weighted average energy costs a more conspicuous difference between the CCE values that included ancillary savings and production benefits and the CCE values for energy savings only, became noticeable. The CCE values that included ancillary savings and production benefits were lower than the weighted average cost of energy for 68 of the projects in the sample (83.9%), while only 57 CCE values that omitted these benefits (70.4%) were below it. If the weighted average cost of energy were to be used as the cost-effective threshold for energy efficiency, these results underscore the fact that when ancillary savings and production benefits are factored into the CCE calculation, a greater number of projects fall under that threshold than when such benefits are omitted from it. This can be seen in Figure 2.

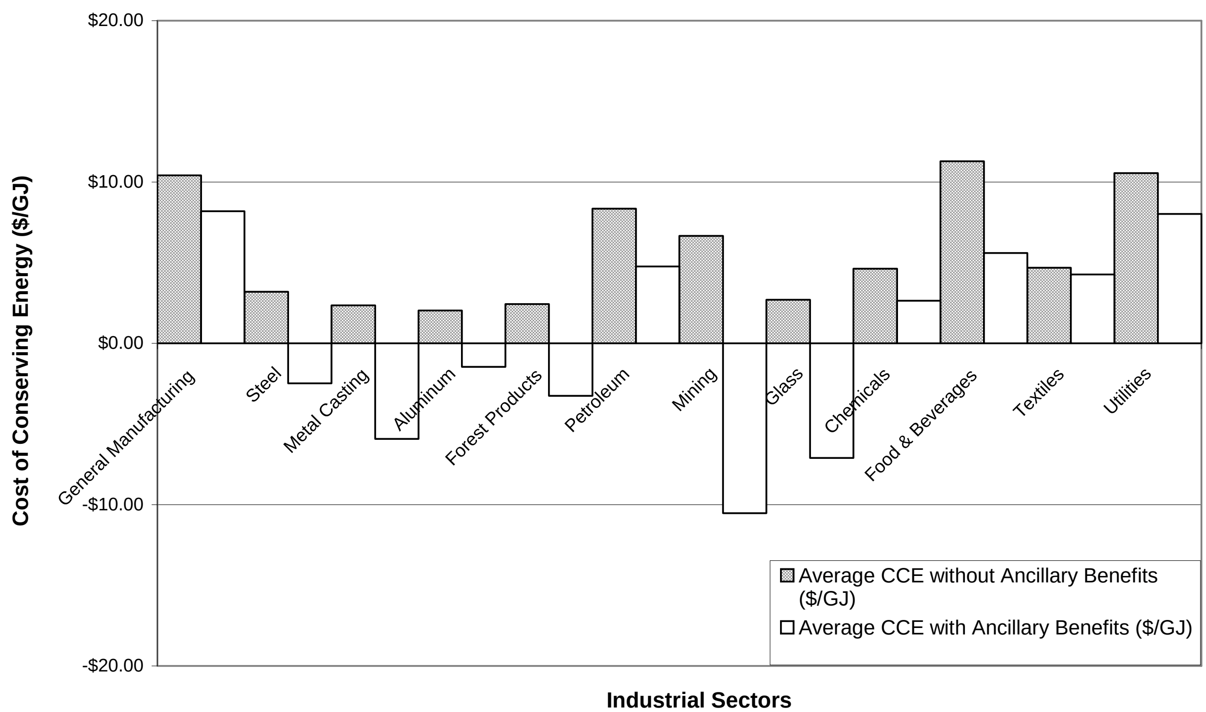
Figure 2: Conservation Supply Curves and the Weighted Average Cost of Energy



Another important result of the CCE analysis is that a significant number of projects yielded negative CCE values when they included ancillary savings and production benefits. This is seen in Figure 2 by the portion of the CSC with ancillary savings and production benefits being below the x-axis. Of the 54 total projects in the data set with quantified ancillary savings and production benefits, 31 (56.4%) produced a negative CCE value. In contrast, all of the CCE values for the projects in the data were positive when only energy savings were used, which suggests that if ancillary savings and production benefits are not factored into the CCE, the costs associated with an energy efficiency measure will always be positive. This indicates the importance of ancillary savings and production benefits in evaluating energy efficiency measures. It also shows that the greater the magnitude of such savings, the greater the likelihood that a CCE will be below the price of energy, or below the cost-effective threshold for energy efficiency.

In Figure 3, an analysis of CCE values that include ancillary savings and those that do not include such savings is presented for the industrial sectors represented in the data set. The first line of the data table displays the average CCE values without ancillary savings and the second line displays the CCE values with ancillary savings for each sector. The third line of the data table displays the percentage change in CCE value. In each case, the CCE value is lower when ancillary savings and production benefits are included in the CCE calculation. In some sectors, the change is quite large, which indicates the magnitude of the ancillary savings. The largest swing was in the mining sector because of strong productivity benefits, while the smallest change was recorded for the textiles sector. This sector had the smallest number of plants in the data set (2) and their ancillary savings were small in comparison to many other plants in the sample.

Figure 3: CCE Values by Industrial Sector[1]



General Manufacturing	Steel	Metal Casting	Aluminum	Forest Products	Petroleum	Mining	Glass	Chemicals	Food & Beverages	Textiles	Utilities
$10.42	$3.20	$2.36	$2.04	$2.43	$8.36	$6.66	$2.71	$4.63	$11.29	$4.68	$10.55
$8.19	-$2.48	-$5.93	-$1.45	-$3.25	$4.77	$10.53	-$7.11	$2.64	$5.60	$4.27	$8.02
21%	178%	351%	171%	234%	43%	258%	363%	43%	50%	9%	24%

A Plant-Level Example

One of the projects in the data set provides a stark example of the impact of ancillary savings in evaluating energy efficiency. In 2001, Lehigh Southwest Cement Company finished an energy efficiency improvement project on the compressed air system at its cement plant in Tehachapi, California. Before the project, plant personnel had to operate the plant's three compressors and rent a 4th unit to satisfy production requirements. Despite this operating scheme, the system experienced severe pressure fluctuations, poor air quality, increasing energy and maintenance costs, and periodic compressor shut downs that

[1] The data from one of the plants in the mining sector was removed because the production benefits were so great that it skewed the results.

interrupted production. The project encompassed a variety of measures including technology upgrades, component reconfiguration, and procedures that lowered compressed air demand.

The project yielded annual energy savings of 900,000 kWh, representing a 13% decrease in compressed air energy consumption, and energy cost savings of $90,000 per year due to the reduced total air demand and stable pressure levels. The compressor shut down rate was eliminated, air quality was improved, and the three existing units were able to satisfy the post-project air demand levels. Production interruptions due to compressor failure ceased, compressor maintenance costs declined by $59,000 annually, and the rental compressor was no longer needed, which saved the plant another $50,000 per year. In addition, the plant achieved a $90,000 rebate from its electric utility. The total costs of implementing the project were $417,000.

When the ancillary savings this project achieved are excluded from the project evaluation, the simple payback is 4.6 years. Even if the rebate is factored into the simple payback calculation, the resulting payback of 3.6 years still exceeds the typical threshold for an industrial energy efficiency project. When entered into the model, the omission of ancillary savings yields a CCE of $18.33/GJ, which is well above the weighted average cost of energy for the data set. Because energy costs for this company were comparatively high ($27.8/GJ), the CCE still falls below this figure, indicating that the project was worthwhile. When the ancillary savings are included, the simple payback for the project falls to 1.64 years and the CCE declines to -$19.27/GJ. While the payback is more attractive with the ancillary savings, it is not among the top ten shortest paybacks in the sample. However, with the ancillary savings, the CCE for this project is the third lowest in the data set. In addition, it has the second greatest, average absolute deviation ($18.80/GJ), which shows the degree of variability between the CCE with ancillary savings and the CCE without ancillary savings. These results are summarized in Table 3.

Table 3: Results for Lehigh Southwest Cement Company

Total project costs	$417,000
Total annual energy cost savings	$90,000
Total annual non-energy savings	$109,000
Total annual savings	$199,000
Rebate payment	$90,000
Simple payback of energy savings	4.63
Simple payback with non-energy benefits	1.64
CCE excluding non-energy benefits	$18.33
CCE including non-energy benefits	-$19.27
Average of absolute deviation	$18.80

Regrettably, the production benefits from the reduced production stoppages were not quantified. This was due in part to the fact that the costs imposed by the production stoppages had not always been measured. The stoppages were of varying length and did not always affect the same production processes, which made it exceedingly complex to attempt to quantify them. Once the project was complete, quantifying such benefits was beyond the project's scope of work. With the inclusion of both ancillary and production benefits the CCE would have been lower.

Conclusion

We have demonstrated that when ancillary savings and production benefits resulting from energy efficiency efforts are incorporated into payback models, the business case for implementing such efforts is more compelling. This is because the impact of ancillary savings and production benefits can be quite significant. Often, ancillary savings and production benefits are left out of many payback calculations of energy efficiency projects in the literature and analysis of industrial energy efficiency. This results in an incomplete understanding of the benefits that are derived from energy efficiency initiatives and of the impact of energy efficiency on a firm's profitability. By using a methodology that integrates ancillary savings and production benefits into a payback calculation such as the CCE, the aggregate benefits of energy efficiency can be revealed.

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